US005503364A

United States Patent [19]

Enomoto et al.

[11] **Patent Number: 5,503,364**

[45] **Date of Patent: Apr. 2, 1996**

[54] **SOLENOID VALVE**

[75] Inventors: **Shigeiku Enomoto**, Aichi; **Toshihiko Igashira**, Toyokawa; **Yasuyuki Sakakibara**, Nishio, all of Japan

[73] Assignee: **Nippon Soken Inc.**, Nishio, Japan

[21] Appl. No.: **141,970**

[22] Filed: **Oct. 28, 1993**

[30] **Foreign Application Priority Data**

Oct. 29, 1992	[JP]	Japan	4-314011
May 21, 1993	[JP]	Japan	5-119623
Jul. 21, 1993	[JP]	Japan	5-179704

[51] **Int. Cl.**^{6} **F16K 31/06**

[52] **U.S. Cl.** **251/129.02**; 251/129.16; 239/585.3

[58] **Field of Search** 251/129.02, 129.15, 251/129.16, 129.08, 129.18; 239/585.1, 585.3

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,690,373 9/1987 Linder et al. .... 251/129.16 X

FOREIGN PATENT DOCUMENTS

61-226529 10/1986 Japan .

Primary Examiner—Martin P. Schwadron
Assistant Examiner—Kevin L. Lee
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A solenoid valve provided with a relief passage by means of which a high-pressure side and a low-pressure side communicate with each other for use, for example, in combination with a fuel injection pump, comprises a valve element capable of being advanced into and retracted from the relief passage, a first compression spring for biasing the valve element in the retracting direction, an armature attached to the rear end of the valve element, an electromagnet for attracting the armature to disconnect the high-pressure side and the low-pressure side from each other by advancing the valve element into the relief passage against the resilience of the first compression coil spring, and a second compression coil spring for holding the armature in a predetermined position close to the electromagnet against the biasing force of the first compression coil spring when the electromagnet is demagnetized.

15 Claims, 13 Drawing Sheets

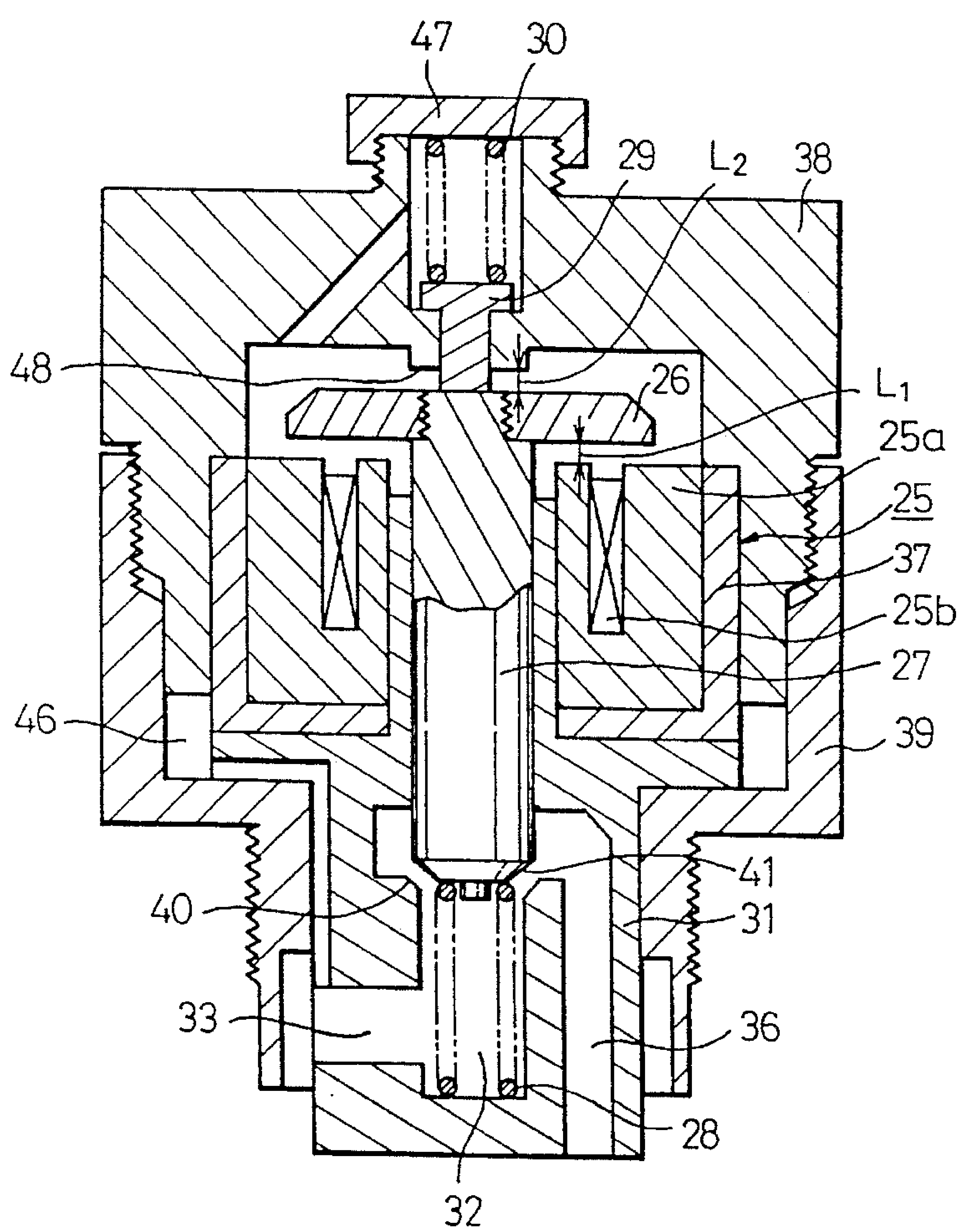


Fig.1

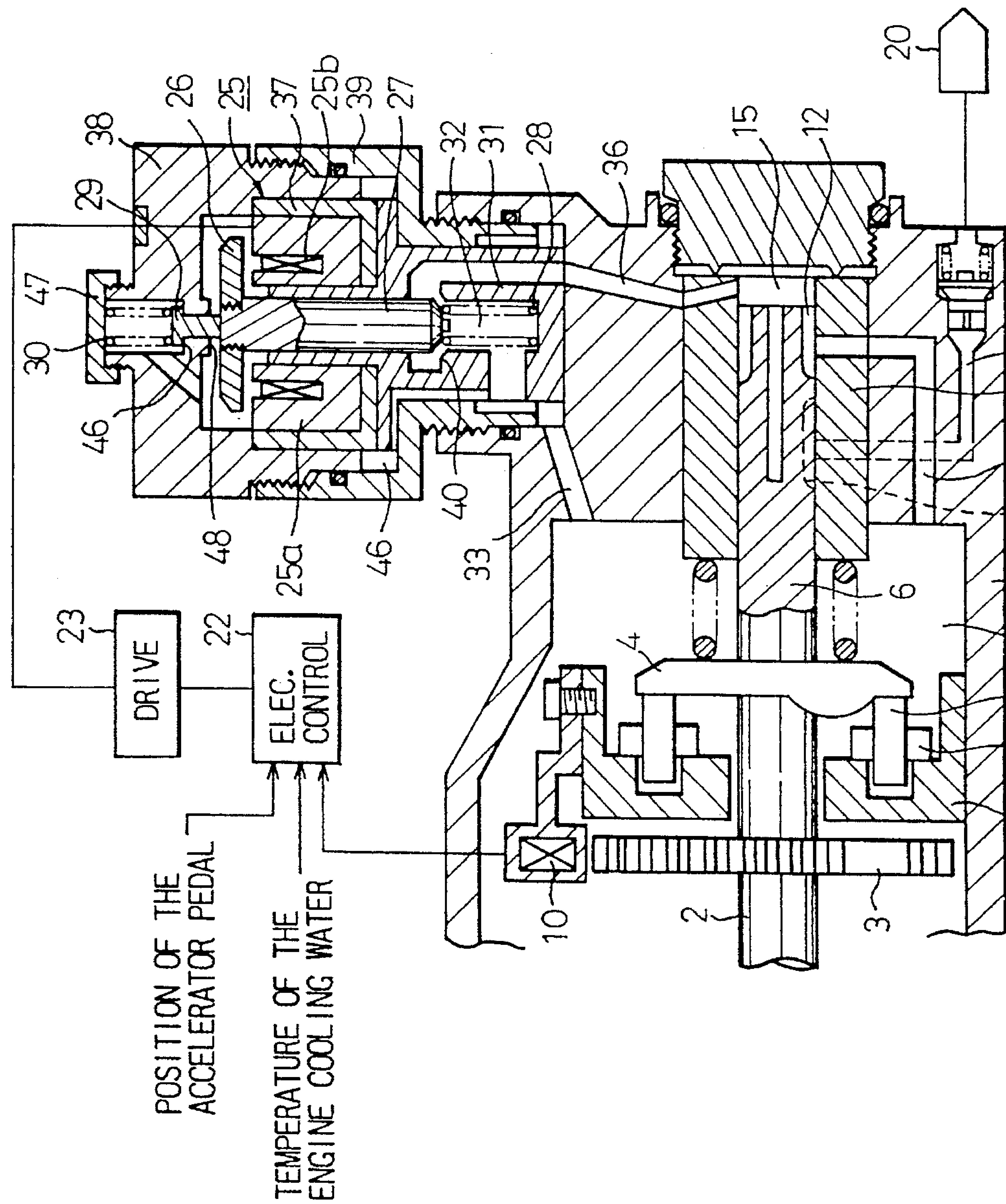

DRIVE
ELEC. CONTROL
POSITION OF THE ACCELERATOR PEDAL
TEMPERATURE OF THE ENGINE COOLING WATER

Fig. 2

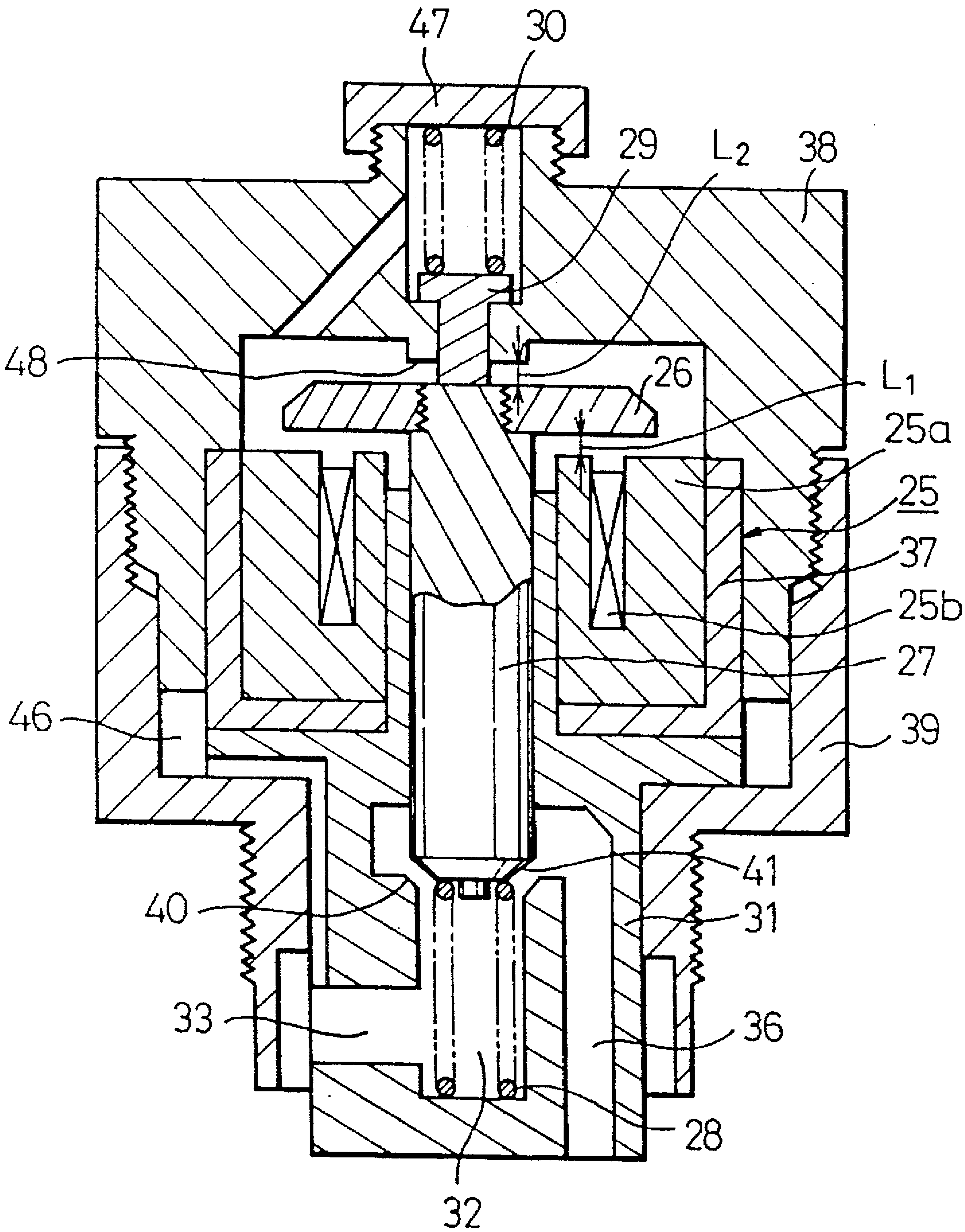


Fig. 3

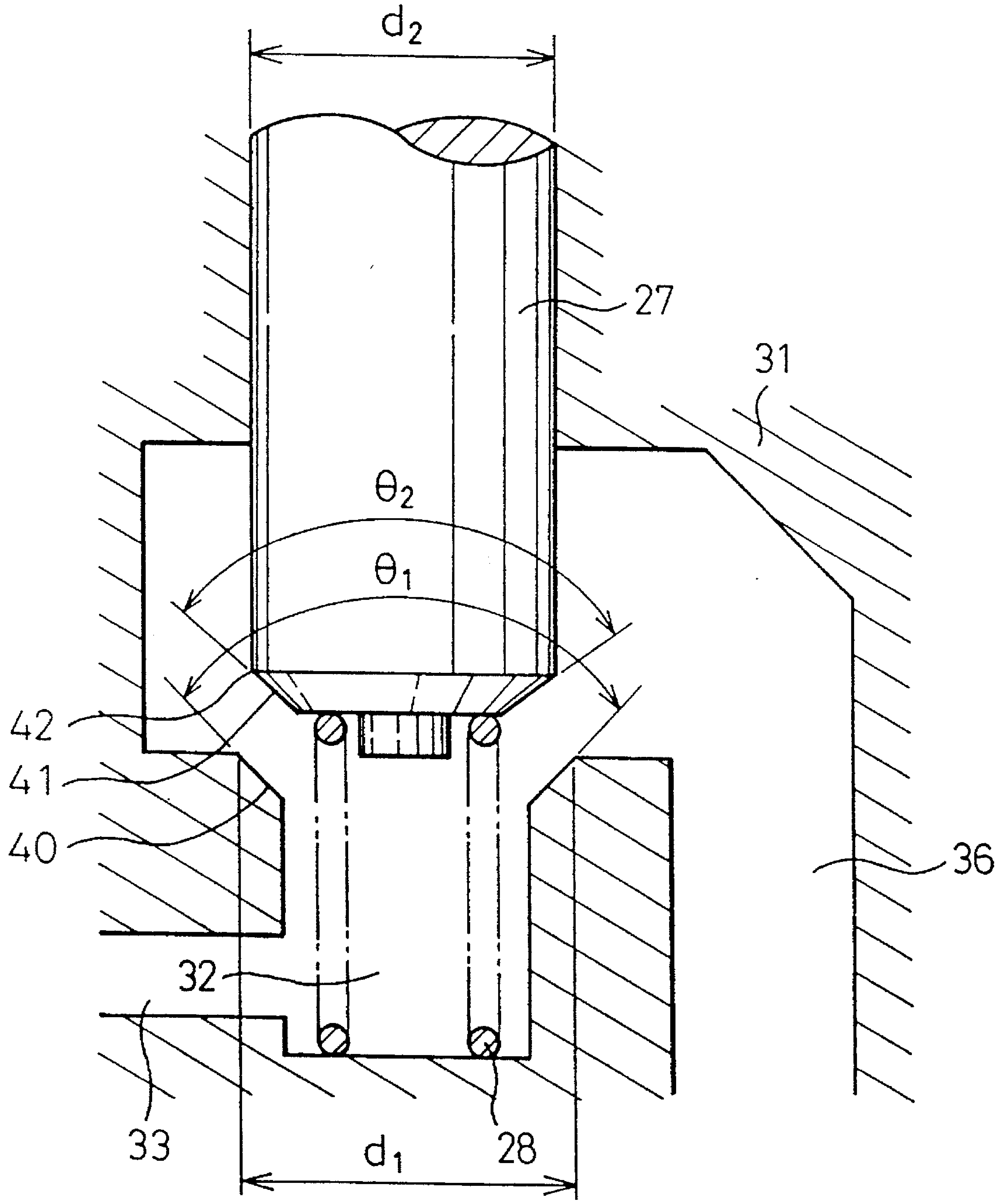


Fig. 4

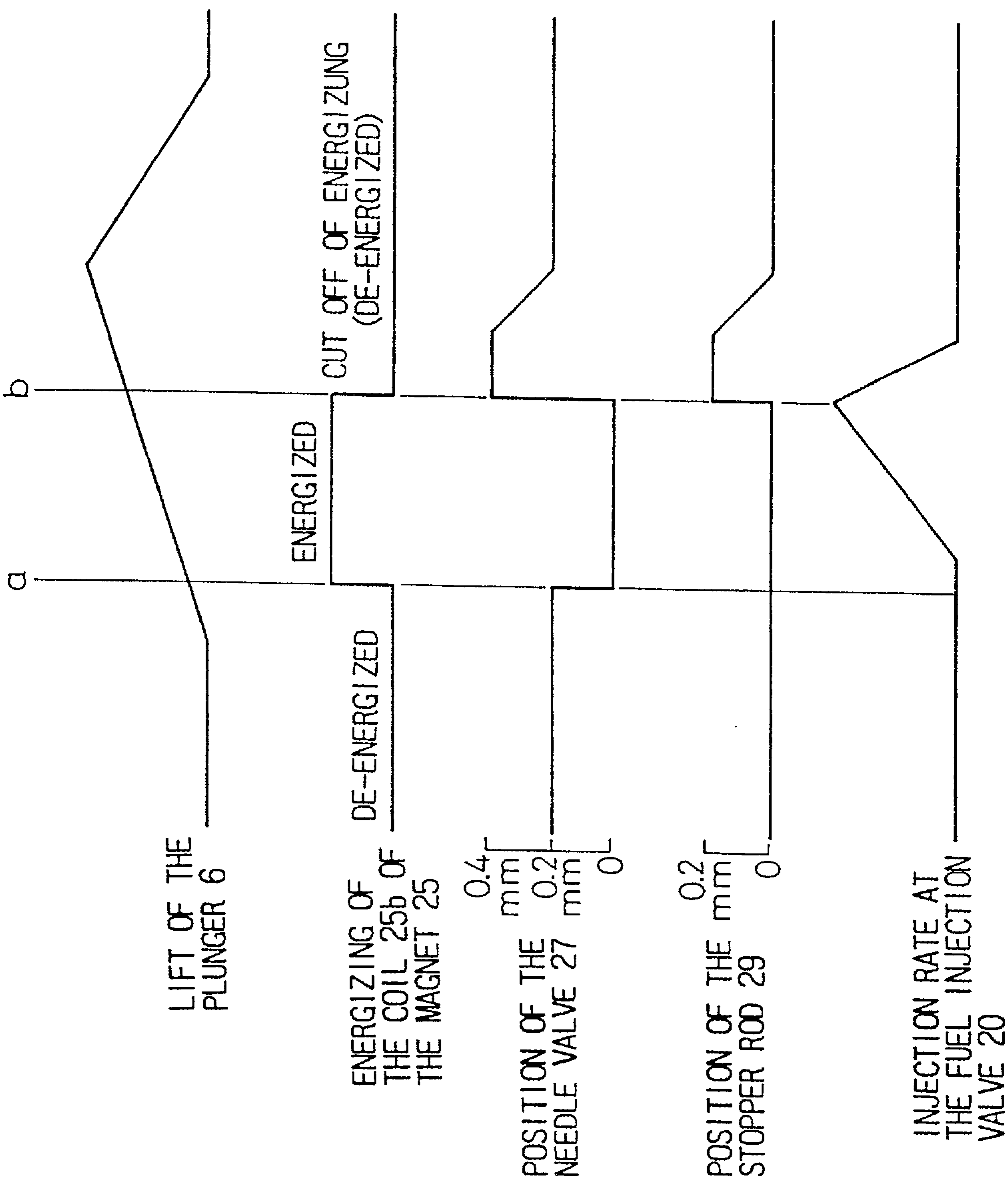

a
b
LIFT OF THE PLUNGER 6
ENERGIZING OF THE COIL 25b OF THE MAGNET 25
DE-ENERGIZED
ENERGIZED
CUT OFF OF ENERGIZUNG (DE-ENERGIZED)
POSITION OF THE NEEDLE VALVE 27
0.4 mm
0.2 mm
0
POSITION OF THE STOPPER ROD 29
0.2 mm
0
INJECTION RATE AT THE FUEL INJECTION VALVE 20

Fig. 5

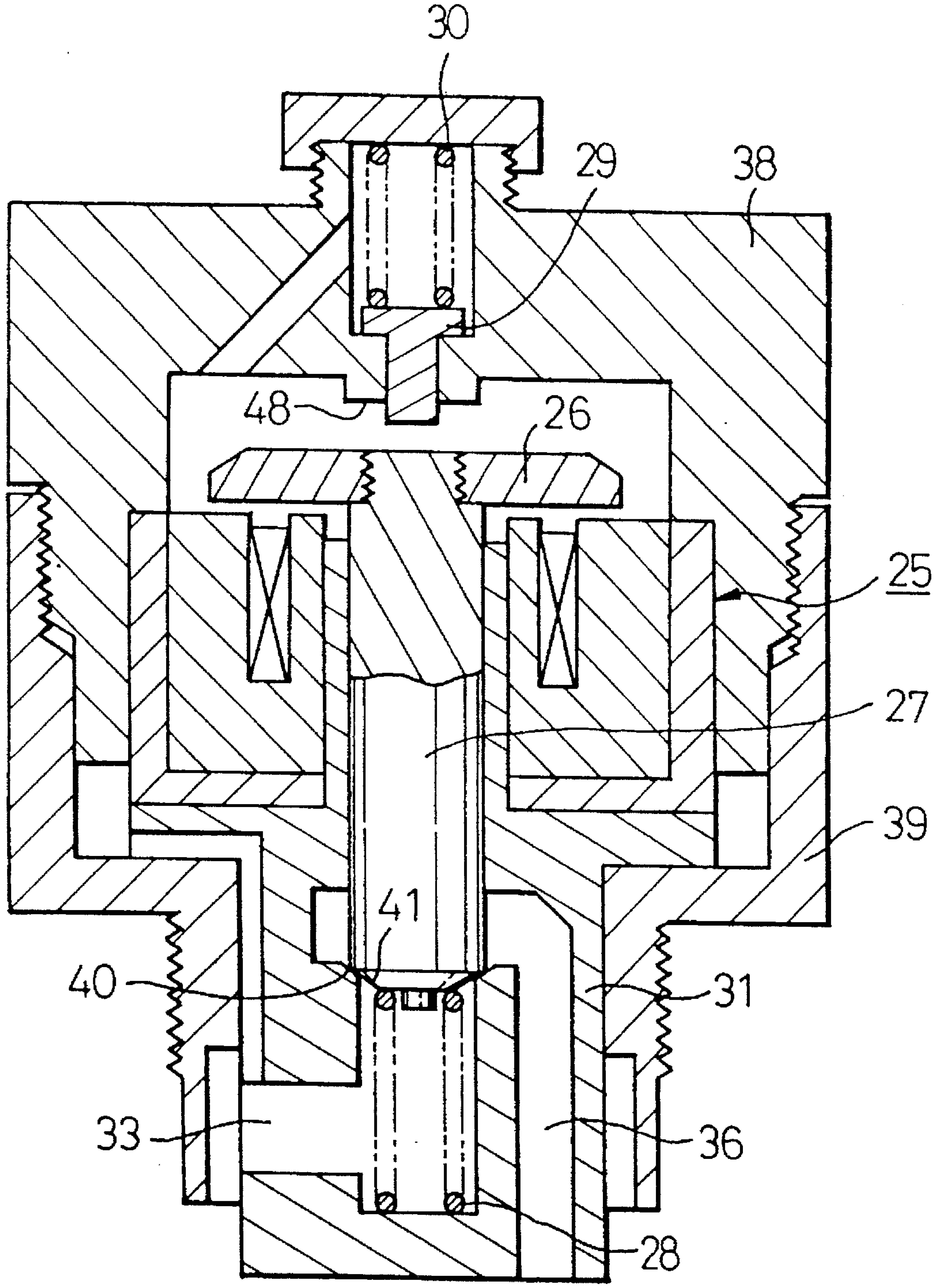


Fig. 6

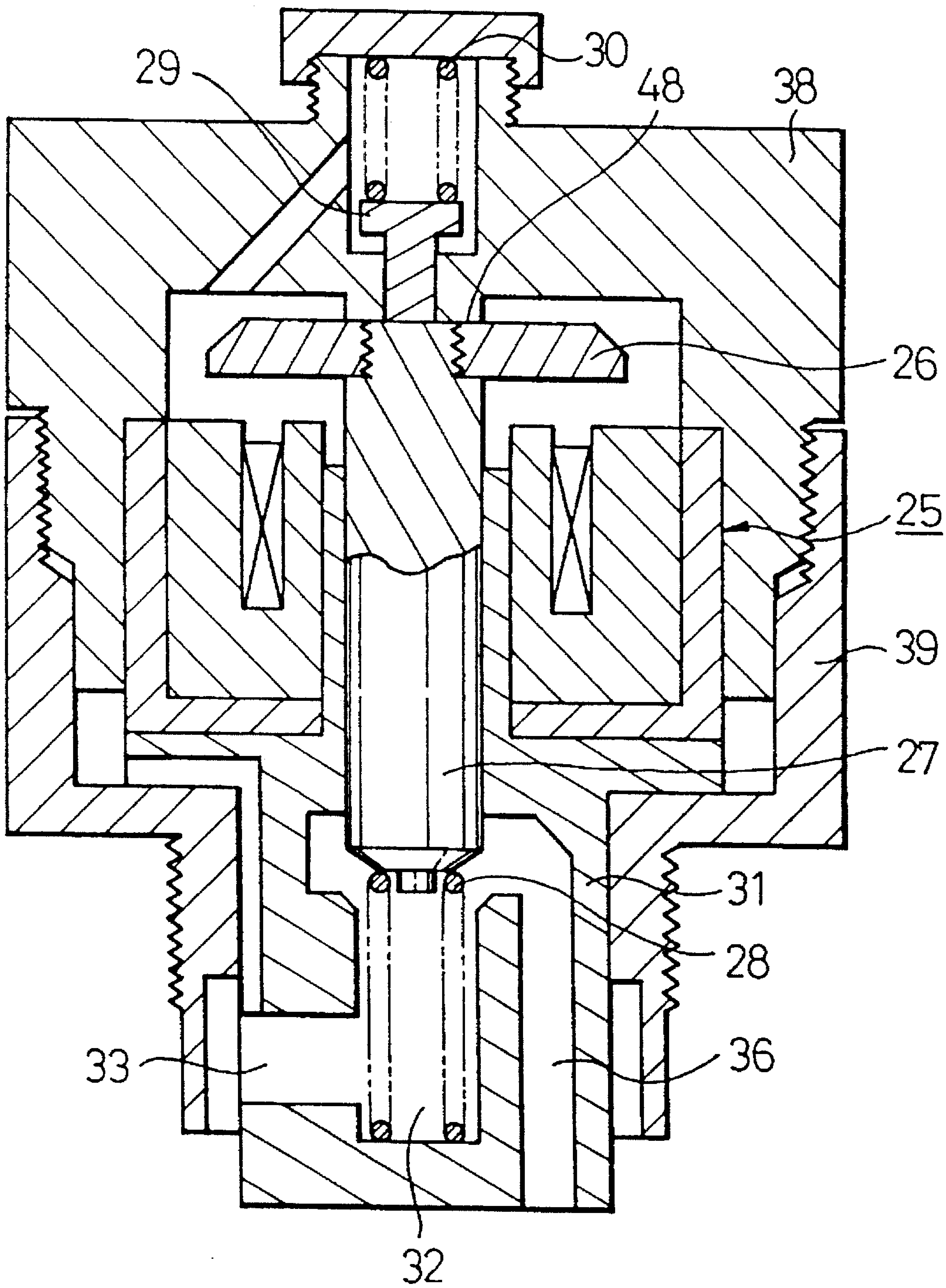


Fig. 7

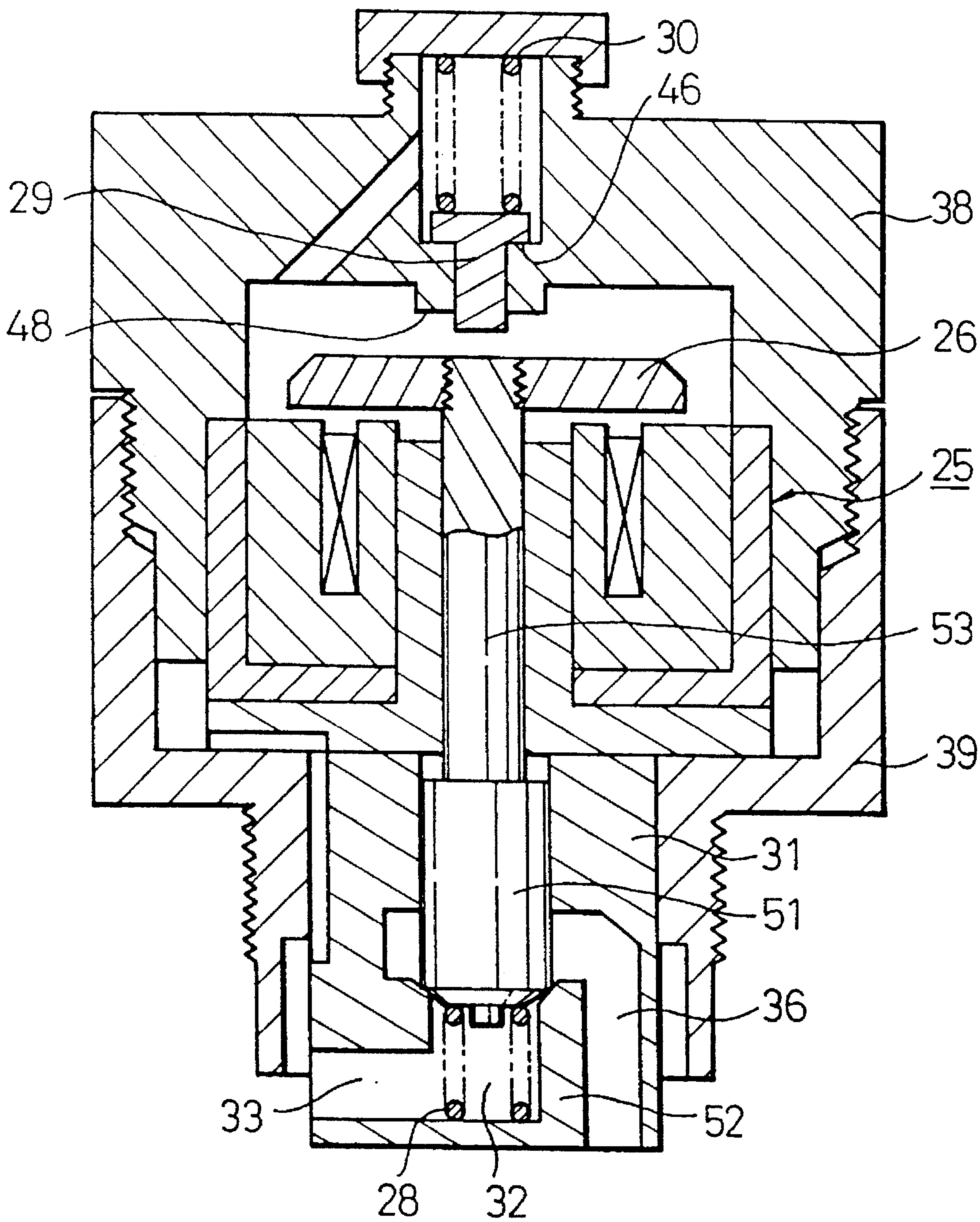


Fig.8

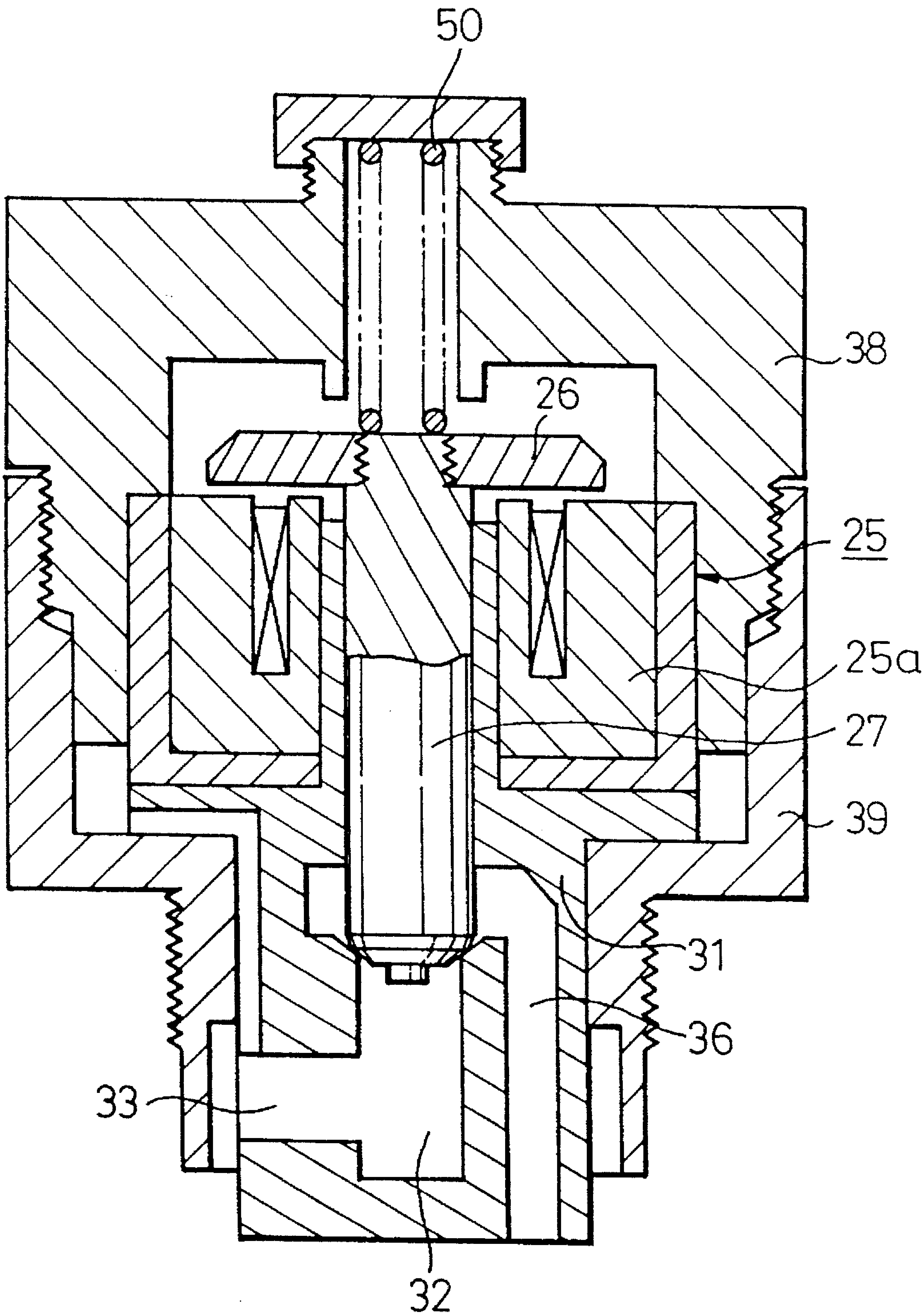


Fig.9

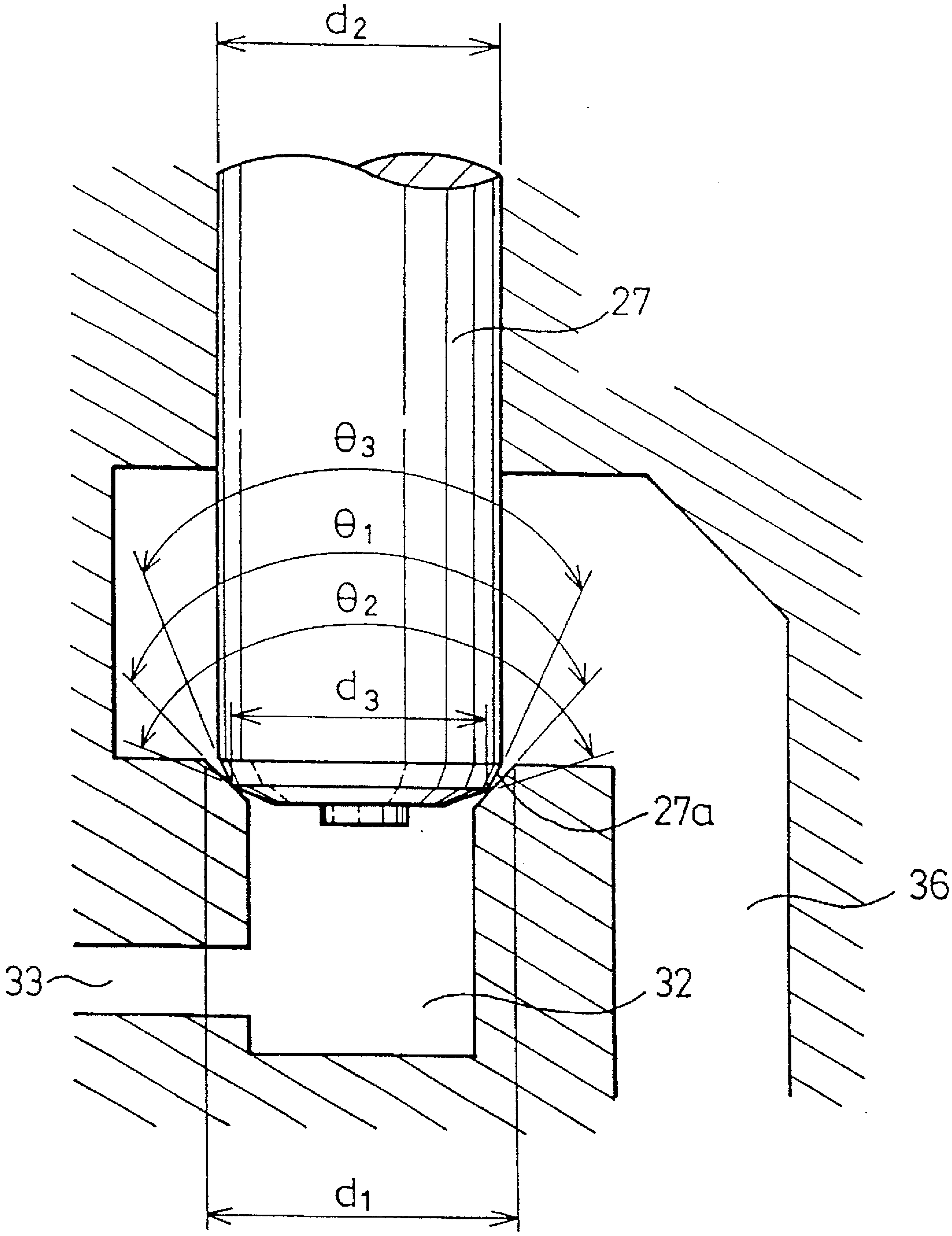


Fig.10

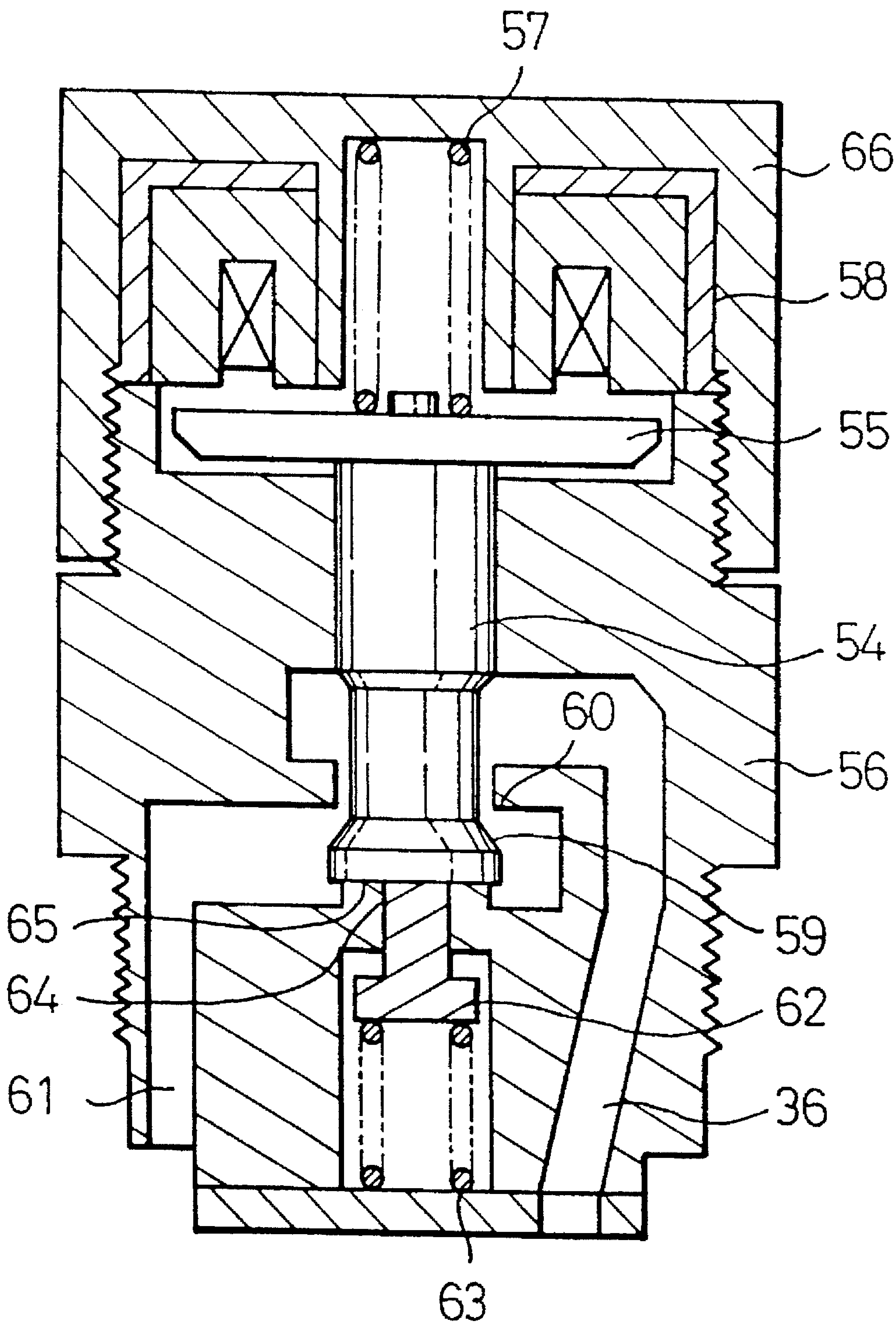


Fig.11

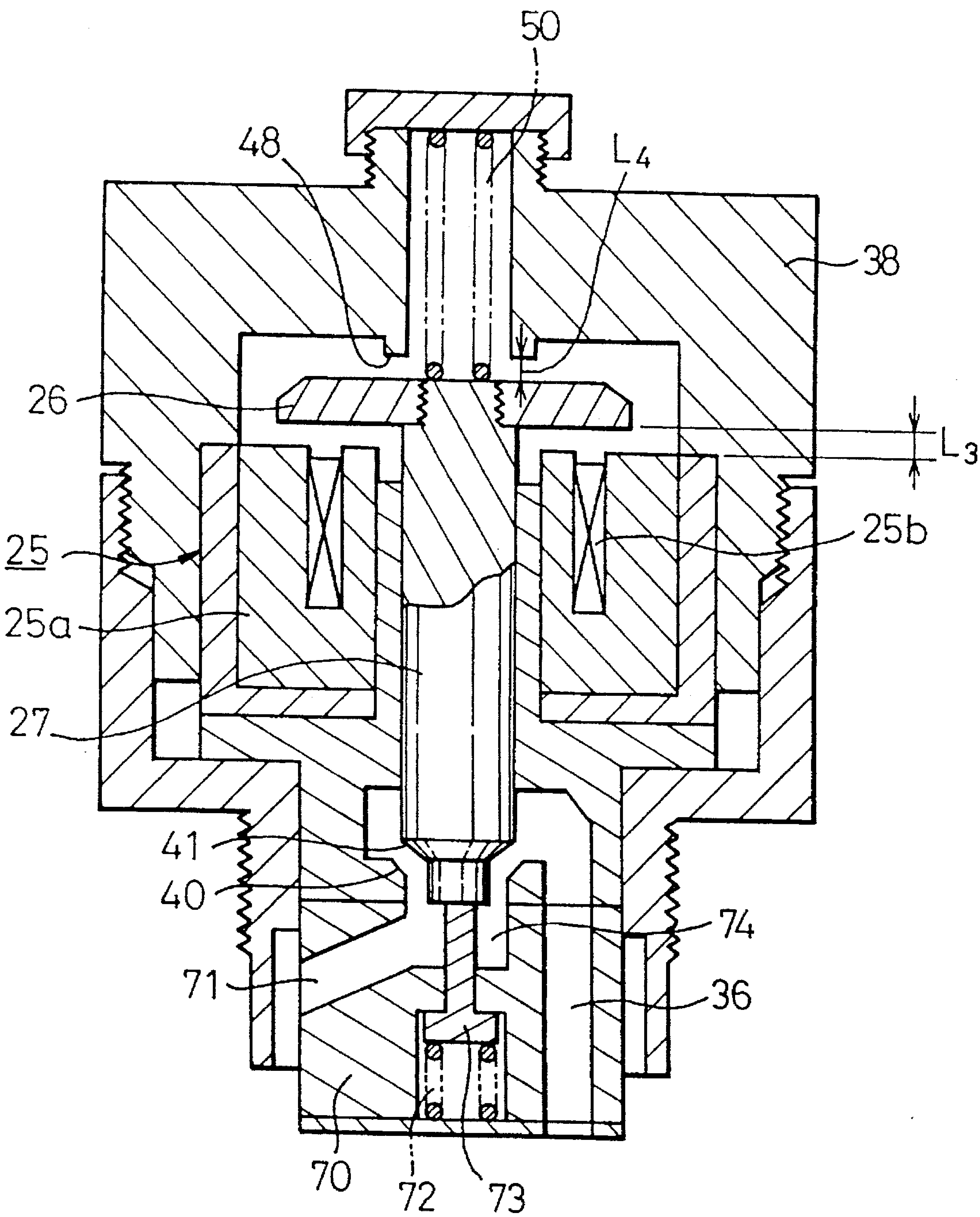


Fig.12

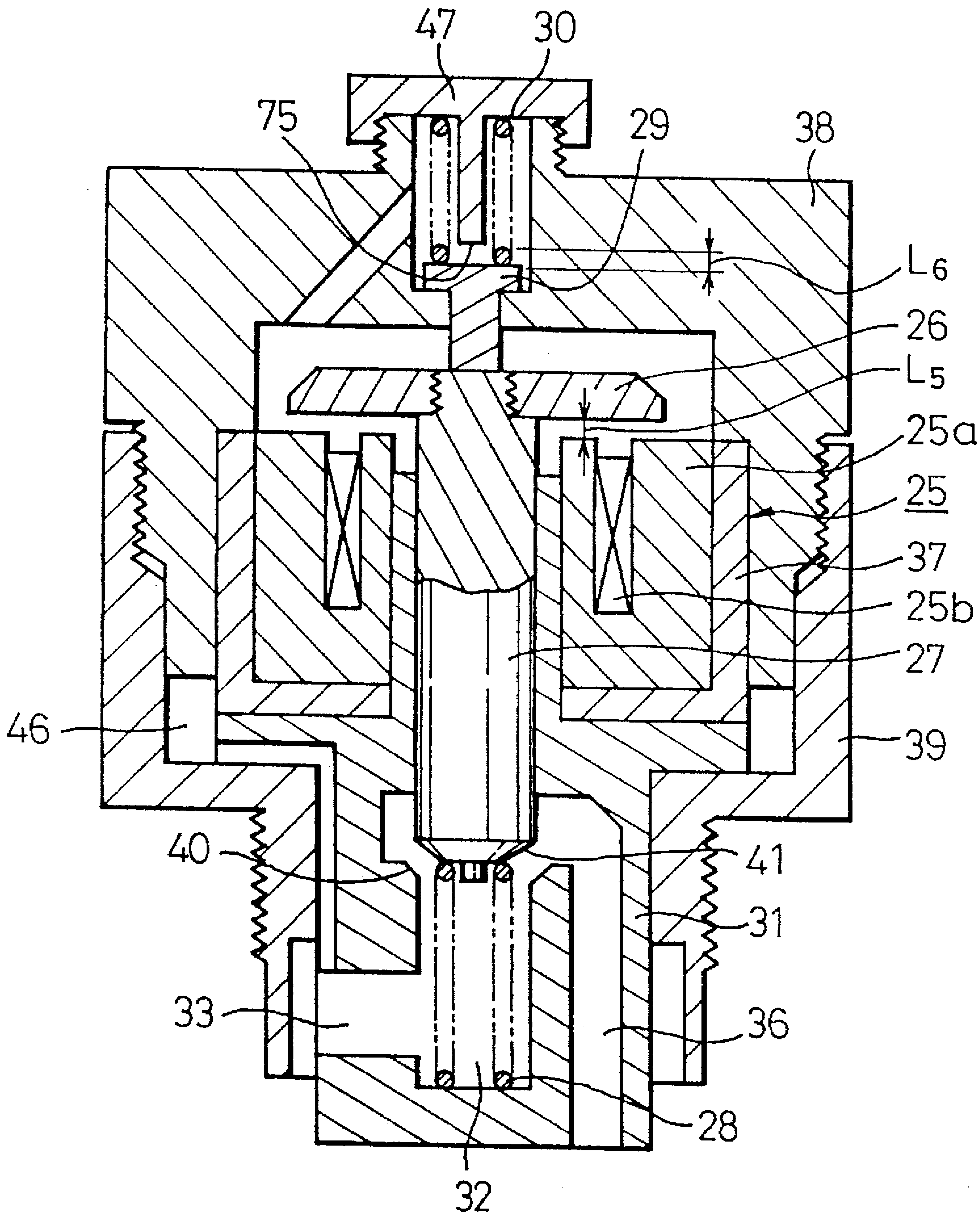
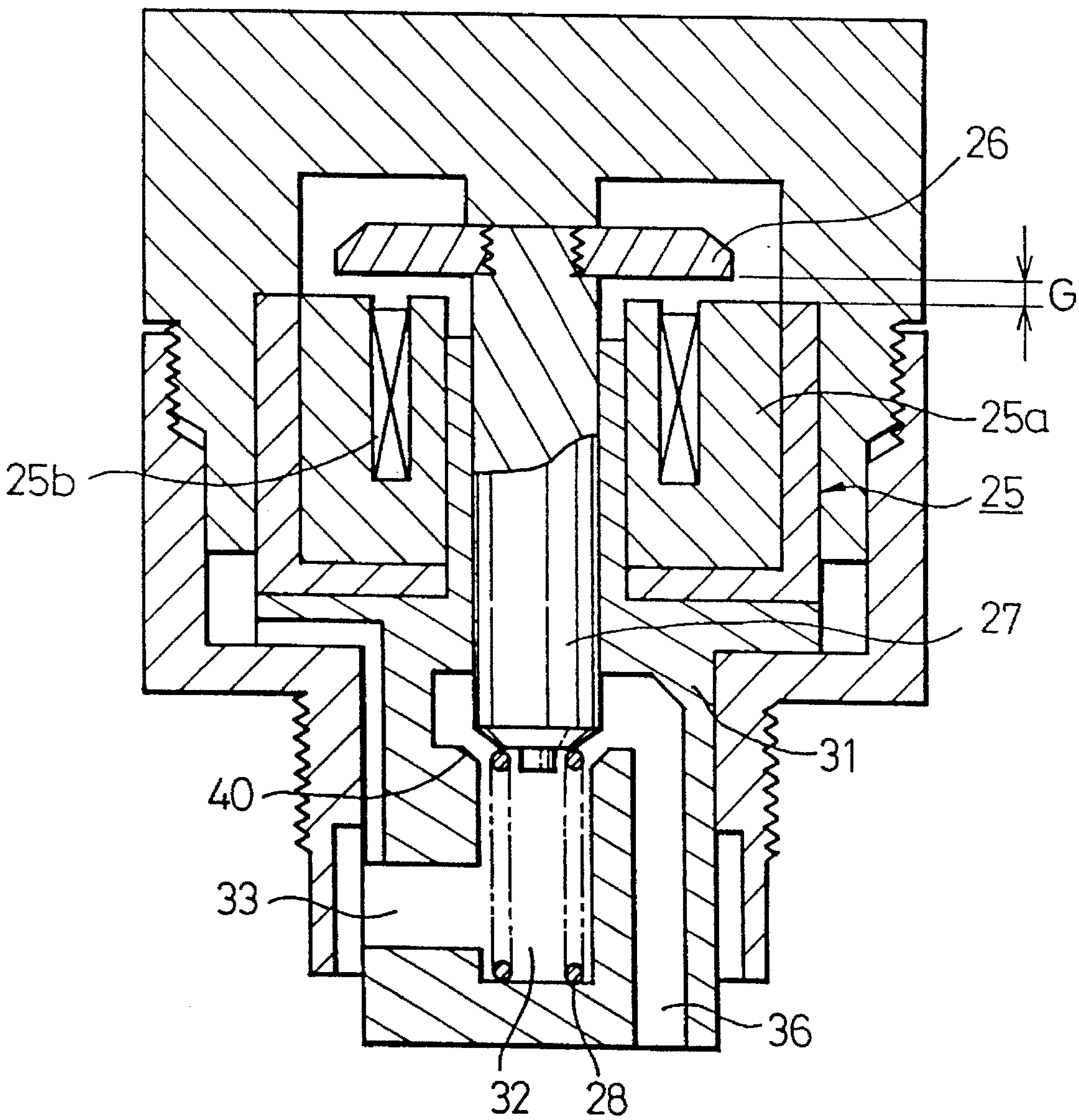


Fig.13

(PRIOR ART)



SOLENOID VALVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a solenoid suitable for use as an electromagnetic spill valve or the like for a fuel injection system.

2. Description of the Related Art

Recently, an electromagnetic spill valve, controlled by a computer, for timed spilling of high-pressure fuel has been proposed. The spilling operation of this known electromagnetic spill valve is controlled by an electronic method instead of a mechanical method. Referring to FIG. **13** showing an electromagnetic spill valve which closes a spill passage when the same is energized, flow passages **33** and **36** are formed in the lower portion of a valve body **31** so as to open respectively in the side surface and the bottom surface of the valve body **31** such that and the flow passages **33** and **36** communicate with each other through of a spring chamber **32**. The flow passages **33** and **36** and the spring chamber **32** serve as portions of the spill passage. A needle valve **27** is supported for axial sliding movement in the upper portion of the valve body **31** with its points facing a seat surface **40** formed in the upper end of the spring chamber **32**. The needle valve **27** is biased upward so as to be separated from the seat surface **40** by a compression coil spring **28** placed in the spring chamber **32**. An electromagnet **25** is mounted on the valve body **31** so as to surround the upper portion of the valve body **31**. The electromagnet **25** comprises a magnetic core **25***a* and an electric solenoid **25***b*. A plate-like armature **26** is fixed to the upper end of the needle valve **27**. When the electric solenoid **25***b* is not energized, an air gap G is formed between the lower surface of the armature **26** and the upper end of the magnetic core **25***a*. The value of the gap G is dependent on the lift of the needle valve **27**. The value of the gap G is, for example, 0.1 mm when the needle valve **27** is seated on the seat surface **40** to close the spill passage. When the electric solenoid **25***b* of the electromagnet **25** is magnetized, the armature **26** is moved downward by magnetic attraction to move the needle valve **27** downward against the resilience of the compression coil spring **28**. When the needle valve **27** is seated on the seat surface **40**, the flow passages **33** and **36** are disconnected from each other.

An engine for a vehicle, for example, requires a fuel injection system capable of injecting high-pressure fuel at a high rate so that of an exhaust gas discharged contains less harmful gases. The consequently, the lift of the needle valve of an electromagnetic spill valve of such a construction must be at least 0.3 mm to provide an opening sufficiently large. However, the value of the air gap G of the electromagnetic spill valve increases when the lift of the needle valve is increased. Since the magnetic attraction of the electromagnet is substantially inversely proportional to the square of the value of the air gap, the maximum lift of the needle valve must be limited to about 0.2 mm, which is contradictory to preferred conditions.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a solenoid valve having an comparatively small electrode magnet and capable of cutting high-pressure fuel suddenly.

In one aspect of the present invention, a solenoid valve provided with a relief passage for discharging part or all of fluid pressurized by a fluid pressurizing means into a low-pressure side, comprising: a relief valve element for opening and closing the relief passage, an electromagnet, an armature to be attracted toward the electromagnet by magnetic force generated by the electromagnet to move the valve element so that the relief passage is closed, a first biasing means for biasing the valve element away from the relief passage to open the relief passage when the electromagnet is not magnetized, and a second biasing means for biasing the the armature so that the armature is positioned in a predetermined range near the electromagnet when the pressure of the fluid prevailing within the relief passage biasing the valve element in an opening direction is not higher than a predetermined level.

When the pressure of the fluid prevailing within the relief passage drops to or below the predetermined level while the relief passage is open, the second biasing means positions the armature in the predetermined range relative to the electromagnet. Therefore, the armature can be attracted toward the electromagnet to close the relief passage with the valve element even if the electromagnet has a comparatively small capacity.

When the electromagnet is demagnetized, the first biasing means moves the valve element in the opening direction. The movement of the valve element in the opening direction is assisted by the pressure of the fluid prevailing within the relief passage if the pressure of the same is comparatively high, so that the armature is moved outside the predetermined range near the electromagnet against the resilience of the second biasing means to fully open the relief passage. Consequently, the high-pressure fluid is discharged quickly through the relief passage. Thus, when this solenoid valve is used as a spill valve, sudden cutting of fuel can be achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following description taken in connection with the accompanying drawings, in which:

FIG. **1** is a sectional view of a fuel injection pump incorporating a solenoid valve of the present invention as a spill valve;

FIG. **2** is a sectional view of a solenoid valve in a first embodiment according to the present invention;

FIG. **3** is an enlarged, fragmentary sectional view of the solenoid valve of FIG. **2**, showing the point of a needle valve and the associated portions of the solenoid valve;

FIG. **4** is a time chart of assistance in explaining the operation of the solenoid valve of FIG. **2**;

FIG. **5** is a sectional view of assistance in explaining the operation of the solenoid valve of FIG. **2**;

FIG. **6** is a sectional view of assistance in explaining the operation of the solenoid valve of FIG. **2**;

FIG. **7** is a sectional view of the solenoid valve in a second embodiment according to the present invention;

FIG. **8** is a sectional view of a solenoid valve in a third embodiment according to the present invention;

FIG. **9** is an enlarged, fragmentary view of the solenoid valve of FIG. **8**, showing the tip of a needle valve and the associated portion of the solenoid valve;

FIG. **10** is a sectional view of a solenoid valve in a fourth embodiment according to the present invention;

FIG. **11** is a sectional view of a solenoid valve in a fifth embodiment according to the present invention;

FIG. **12** is a sectional view of a solenoid valve in a sixth embodiment according to the present invention; and

FIG. **13** is a sectional view of a known solenoid valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

Referring to FIG. **1** showing a fuel injection pump incorporating a solenoid valve in a first embodiment according to the present invention as a spill valve, the fuel injection pump has a pump unit having a casing **17**, a drive shaft **2** disposed within and supported for rotation on the casing **17**, and a face cam **4** connected to the drive shaft **2** by a known coupling and having a cam surface. The face cam **4** is biased by a spring toward rollers **7** supported on a roller support ring **9** so that the cam surface is kept in contact with the rollers **7**. When the drive shaft **2** rotates, the face cam **4** reciprocates periodically along the axis of the drive shaft **2**, namely, in horizontal directions as viewed in FIG. **1**. A plunger **6** is slidably fitted in a cylinder **16** so as to form an expandable pressure chamber **15** in the cylinder **16**. The plunger **6** reciprocates axially together with the face cam **4**. When the plunger **6** is advanced, toward the bottom of the cylinder **16**, fuel filling the pressure chamber **15** is pressurized and the pressurized fuel flows through a distribution port **11** and a distribution passage **21** into an injection valve **20**. When the plunger **6** is retracted, away from the bottom of the cylinder **16**, the fuel contained in a low-pressure chamber **18** is sucked through a suction passage **19** and a suction groove **12** into the pressure chamber **15**.

The pressure chamber **15** communicates with a flow passage formed in the valve body **31** of the solenoid valve mounted on the top face of the casing **17** and connected to a spring chamber **32** formed in the valve body **31** by means of a high-pressure passage **36** formed through the casing **17**. A low-pressure passage **33** is formed in the valve body **31**. The low-pressure passage **33** has one end connected to the spring chamber **32** and the other end opening into the low-pressure chamber **18**. A seat surface **40** is formed at the upper end of the spring chamber **32**, and a needle valve **27** is disposed coaxially with the seat surface **40** so as to be seated closely on the seat surface **40**. A cylindrical valve housing **39** housing the valve body **31** is fixedly screwed on the upper end of the casing **17** with screws, and an upper housing **38** is fixedly screwed on the open upper end of the housing **39** to close the open upper end.

An electronic controller **22** receives a cylinder discriminating signal and an engine speed signal from a pickup **10** capable of detecting individual teeth formed on a signal roller **3** mounted on the drive shaft **2**. The electronic pump controller **22** also receives signals representing the position of the accelerator pedal, the temperature of engine cooling water and such. The electronic controller **22** determines an optimum fuel injection timing and an appropriate amount of fuel to be forced into the combustion chamber in each fuel injection cycle on the basis of the input signals, and controls a driving circuit **23** for driving the coil **25*b*** of an electromagnet **25** included in the solenoid valve.

Referring to FIG. **2**, the needle valve **27** is fitted vertically slidably, as viewed in FIG. **2**, in a central hole formed in the valve body **31** with its tapered tip facing the seat surface **40** having a conical shape. The needle valve **27** is biased upward, as viewed in FIG. **2**, with a compression coil spring **28** placed within the spring chamber **32**. A plate-like armature **26** is fixed to the upper end of the needle valve **27**. The magnetic core **25*a*** and the coil **25*b*** of the electromagnet **25** are held on a nonmagnetic stator housing **37** put on a cylindrical wall of the valve body **31** through which the needle valve **27** is extended. When the coil **25*b*** is not energized, the armature **26** is positioned with a small gap between the lower surface thereof and the upper end of the magnetic core **25*a*** of the electromagnet **25**. The space containing the armature **26** communicates with the low-pressure chamber **18** by means of a pressure equalizing passage, not shown, so that the same pressure as that of the low-pressure chamber **18** prevails within the space. The upper end of the needle valve **27** penetrating the armature **26** is in contact with the lower end of a stopper rod **29** projecting downward from the lower surface of the upper wall of the upper housing **38**. The T-shaped head of the stopper rod **29** is positioned in a spring chamber formed in the upper wall of the upper housing **38**, and a compression coil spring **30** is placed in the spring chamber so as to be compressed between a cap **47** closing the spring chamber, and the T-shaped head of the stopper rod **29** to bias the stopper rod **29** downward.

In a state shown in FIG. **2**, in which the coil **25*b*** of the electromagnet **25** is not energized and the pressure of the fluid in the flow passages **23**, **33** and **36** is the same as that in the low-pressure chamber **18**, for example, 5 atm, the interval L_1 between the upper end of the magnetic core **25*a*** and the lower surface of the armature **26** is 0.3 mm, the interval L_2 between the upper surface of the armature **26** and the lower end of a boss **48** formed in the inner surface of the upper wall of the upper housing **38** is 0.2 mm, the preload on the compression coil spring **28** is 5 kg, and the preload on the compression coil spring **30** is 11 kg.

Referring to FIG. **3** showing the shape of the tip of the needle valve **27** in detail, the seat surface **40** is a portion of a circular cone having an apex angle θ_1 of 119° and has an upper end, i.e., a larger end, having a diameter d of 8.2 mm, and the needle valve **27** has a diameter d of 8.0 mm and a tapered sealing face **41** having the shape of a portion of a circular cone having an apex angle θ_2 of 120°. When the needle valve **27** rests on the seat surface **40**, the upper edge **42** of the sealing face **41** of the needle valve **27** is in close contact with the seat surface **40** to disconnect the flow passages **33** and **36** from each other. The pressure of the fuel in the flow passage **36** acts radially on the needle valve **27** when the needle valve **27** rests on the seat surface **40** and hence the movement of the needle valve **27** is not affected by the pressure of the fuel in the flow passage **36**.

The operation of the solenoid valve thus constructed will be described hereinafter with reference to FIG. **4**.

Supply of current to the coil **25*b*** of the electromagnet **25** is started at a predetermined moment (point a in FIG. **4**) after the start of advancement, namely, rightward movement as viewed in FIG. **1**, of the plunger **6**. Since the interval L_1 of 0.3 mm between the magnetic core **25*a*** of the electromagnet **25** and the armature **26** is small enough for the magnetic force generated by the electromagnet **25** to act effectively on the armature **26**, the armature **26** is attracted without fail toward the electromagnet **25**. Consequently, the lift of the needle valve **27** decreases to 0 mm, i.e., the sealing face **41** of the needle valve **27** comes into close contact with the seat surface **40**, to disconnect the flow passages **33** and **36** from each other as shown in FIG. **5**. In this state, the interval L_1 is 0.1 mm. As the plunger **6** advances further, the pressure of the fuel within the pressure chamber **15** increases, and the high-pressure fuel is supplied through the distribution passage **21** to the fuel injection valve **20**. Upon the increase of the pressure of the high-pressure fuel beyond a predetermined level, the fuel injection valve **20** starts injecting the high-pressure fuel.

After a predetermined, measured quantity of fuel has been injected, the supply of current to the coil **25***b* of the electromagnet **25** is stopped at a point b (FIG. **4**), and then the needle valve **27** is raised by the resilience of the compression coil spring **28** to enable the flow passage **33** and **36** to communicate with each other by means of the pressure chamber **32**. Then, the high-pressure fuel flows through the flow passage **36** into the spring chamber **32** to urge the needle valve **27** upward and, consequently, the needle valve **27** is moved further upward to move the stopper rod **29** upward against the resilience of the compression coil spring **30** after the upper end of the needle valve **27** has been brought into contact with the stopper rod **29** until the upper surface of the armature **26** comes into contact with the lower surface of the boss **48** formed on the inner surface of the upper wall of the upper housing **38** as shown in FIG. **6**. In this state, the lift of the needle valve **27** is 0.4 mm and a sufficiently large gap is secured between the seat surface **40** and the sealing face **41** of the needle valve **27** to spill the high-pressure fuel quickly. Consequently, the pressure of the fuel in the pressure chamber **15** drops rapidly to cut the fuel injection by the fuel injection valve **20** suddenly.

As the pressure of the fuel in the flow passages **33** and **36** decreases, the stopper rod **29** is moved downward by the resilience of the compression coil spring **30** to push down the armature **26** to the position, shown in FIG. **2**, where the armature **26** is to be located before starting the fuel injection cycle.

Since the armature is positioned very near to the electromagnet **25** before the start of the fuel injection cycle in which the pressure of the fuel in the flow passages is on a low level, the electromagnet is able to attract the armature **26** surely when energized to secure the reliable flow passage closing action of the needle valve **27**, even if the capacity of the electromagnet **25** is comparatively small. When the electromagnet **25** is demagnetized to release the armature **26**, the movement of the needle valve **27** away from the seat surface **40** caused by the compression spring **28** is assisted by the pressure of the fuel so that the needle valve **27** rises raising the stopper rod **29** and separated sufficiently from the seat surface **40**. Accordingly, the injection of the fuel can be sharply cut.

The compression coil springs **28** and **30** may be substituted by elastic rubber members.

Second Embodiment

Referring to FIG. **7**, a solenoid valve in a second embodiment according to the present invention is provided with a needle valve **51**, a stem of which is smaller than that of the needle valve **27** of the first embodiment. A push rod **53** having a comparatively small diameter is fitted axially slidably in the axial, central hole of an electromagnet **25** with its lower end in contact with the upper end of the needle valve **51**, and an armature **26** is attached to the upper end of the push rod **53**. When energized, the electromagnet **25** attracts the armature **26** to push the needle valve **51** down by the push rod **53** in order that the flow passages **33** and **36** are disconnected from each other as shown in FIG. **7**. Since the total mass of the needle valve **27** and the push rod **53** is smaller than the mass of the needle valve **27** of the first embodiment, the response of the solenoid valve in the second embodiment for opening and closing operations is faster than that of the solenoid valve in the first embodiment.

Third Embodiment

Referring to FIG. **8**, a solenoid valve in a third embodiment according to the present invention is not provided with any means like the compression coil springs **28** of the foregoing embodiments in a chamber **32** corresponding to the spring chambers **32** of the foregoing embodiments. This solenoid valve, having a tip formed in a shape as shown in FIG. **9**, employs a high pressure fluid acting upon a valve sealing face of a needle valve **27** as the first biasing means. As shown in FIG. **9**, the sealing face of the tip of the needle valve **27** consists of an upper conical face **27***a*, which is a portion of a circular cone having an apex angle of θ_3 smaller than the apex angle θ_1 of a circular cone forming a seat surface, and a lower conical face, which is a portion of a circular cone having an apex angle of θ_2. When a high pressure P of the fuel acts on the upper conical face **27***a* while the needle valve **27** is seated on the seat surface, an upward force of $\pi\cdot(d_2^2-d_3^2)\cdot P/4$, where d_2 is the diameter of the upper end of the upper conical face **27***a* equal to the diameter of the needle valve **27**, and d_3 is the diameter of the lower end of the upper conical face **27***a*, acts on the needle valve **27**, so that the needle valve **27** is moved upward by this force when the electromagnet **25** is demagnetized.

Since the needle valve **27** is moved away from the seat surface by the action of the high-pressure fuel, the needle valve **27** can be biased downward directly by a compression coil spring **50** to locate an armature **26** in a range near the magnetic core **25***a* of the electromagnet **25** before starting the fuel injection cycle as shown in FIG. **8**. Thus, this solenoid valve needs less component parts than the solenoid valves in the foregoing embodiments and has a simple construction. When the needle valve **27** of the first embodiment is provided with a conical surface like the upper conical surface **27***a* of the needle valve **27** of the third embodiment, the preload on the compression coil spring **28** may be reduced.

Fourth Embodiment

Referring to FIG. **10**, a solenoid valve in a fourth embodiment according to the present invention is provided with a needle valve **54** for disconnecting a high-pressure flow passage **36** and a low-pressure flow passage **61** extends through a wall on which a seat surface **60** is formed. When the needle valve **54** is raised, a sealing face **59** formed on the circumference of an expanded portion of the needle valve **54** comes into close contact with the seat surface **60** to disconnect the flow passages **36** and **61** from each other.

An electromagnet **58** is disposed above an armature **55** attached to the upper end of the needle valve **54**, and mounted on a central boss projecting downward from the inner surface of the upper wall of an upper housing **66**. The armature **55** is biased downward together with the needle valve **54** by a compression coil spring **57** placed within the central boss of the upper housing **66**. When the electromagnet is magnetized, the armature **55** is, together with the needle valve **54**, attracted toward the electromagnet **58**, so that the sealing face **59** of the needle valve **54** comes into close contact with the seat surface **60** to disconnect the flow passages **36** and **61** from each other. A stopper rod **62** is placed in a hole formed in a valve body **56** below the needle valve **54** and is biased upward with a compression coil spring **63** so that the upper end thereof is in contact with the lower end of the needle valve **54** positioned within the low-pressure flow passage **61** while the electromagnet **58** is not magnetized.

In a state where the low-pressure fuel prevails within the flow passages **36** and **61**, the stopper rod **62** is biased upward to lift the needle valve **54** by a predetermined amount so that the armature **55** is located close to the electromagnet **58**. Accordingly, a sufficiently intense magnetic field is applied to the armature **55** and the needle valve **54** can be surely moved to a closed position when the electromagnet **58** is magnetized.

When the electromagnet **58** is demagnetized after the pressure of the fuel prevailing in the high-pressure flow passage **36** has increased to a predetermined level, the needle valve **54** is moved downward by the combined action of the resilience of the compression coil spring **57** and the pressure of the fuel to connect the flow passages **36** and **61**. The needle valve **54** is thus moves downward, depressing the stopper rod **62**, until the lower end of the needle valve **54** comes into contact with a boss **65** formed on the inner surface of the valve body **56** as shown in FIG. **10**, so that a sufficiently wide space is formed between the sealing face **59** and the seat surface **60**. Consequently, the injection of the fuel can suddenly be cut.

Fifth Embodiment

Referring to FIG. **11**, a solenoid valve in a fifth embodiment according to the present invention is provided with a needle valve **27**, for disconnecting flow passages **36** and **71**, biased in the closing direction with a compression coil spring **50**. The preload on the compression coil spring **50** is, for example, 6 kg. A stopper rod **73** is placed in a distance piece **70** disposed below the needle valve **27** and biased upward with a compression coil spring **72** so that the upper end of the same is in contact with the tip of the needle valve **27**. The preload on the compression coil spring **72** is, for example, 11 kg. The compression coil spring **72** biases the needle valve **27** through the stopper rod **73** in the opening direction. When the lift of the needle valve **27** increases beyond 0.2 mm, the needle valve **27** is separated from the stopper rod **73** and the biasing force of the compression coil spring **72** does not act on the needle valve **27**.

In a state where an electromagnet **25** is not magnetized and the pressure of the fuel prevailing in the flow passages **36** and **71** is equal to that of the fuel prevailing within a low-pressure chamber **18**, for example, 5 atm, the interval L_3 between the magnetic core **25*a*** of the electromagnet **25** and the lower surface of an armature **26** attached to the upper end of the needle valve **27** is 0.3 mm, and the interval L_4 between the upper surface of the armature **26** and a boss **48** formed on the inner surface of the upper wall of an upper housing **38** is 0.2 mm. When the coil **25*b*** of the electromagnet **25** is energized, the armature **26** is attracted toward the electromagnet **25** to move the needle valve **27** downward so that the sealing face **41** of the needle valve **27** comes into close contact with a seat surface **40** to disconnect the flow passages **36** and **71** from each other. In this state, the interval L_3 is 0.1 mm.

Upon the de-energization of the coil **25*b*** of the electromagnet **25**, the needle valve **27** is raised by the resilience of the compression coil spring **72** to connect the flow passages **36** and **71**. Consequently, the high-pressure fuel flows into a flow passage **74** under the needle valve **27** to urge the needle valve **27** upward against the resilience of the compression coil spring **50** until the armature **26** comes into contact with a boss **48** formed in the inner surface of the upper housing **38**. In this state, the lift of the needle valve **27** is 0.4 mm.

The solenoid valve in the fifth embodiment is advantageous over the solenoid valve in the first embodiment in the following respects.

Whereas the preload on the compression coil spring **28** of the solenoid valve in the first embodiment can be adjusted by means of shims or the like, not shown, so that the needle valve **27** is seated on the seat surface **40** when a current Is (A) is supplied to the coil **25*b*** of the electromagnet **25**, the preload on the compression coil spring **30** of the solenoid valve in the first embodiment cannot be adjusted in such a manner.

Meanwhile, in the fifth embodiment, both the preload on the compression coil spring **50** and the preload on the compression coil spring **72** can be adjusted to appropriate values by first adjusting the preload on the compression coil spring **72** in a state where the compression coil spring **50** is removed so that the needle valve **27** is seated on the seat surface **40** when a current I_2 (A) is supplied to the coil **25*b*** of the electromagnet **25**, and secondly adjusting the preload on the compression coil spring **50** so that the needle valve **27** is seated on the seat surface **40** when a current I_3 (A) is supplied to the coil **25*b*** of the electromagnet **25**.

Sixth Embodiment

Referring to FIG. **12**, a solenoid valve in a sixth embodiment according to the present invention is provided with a cap **47** having a projection **75** projecting from the inner surface of the upper wall thereof. The function of the projection **75** is equivalent to the boss **48** formed on the inner surface of the upper wall of the upper housing **38** of the solenoid valve in the first embodiment.

In a state where an electromagnet **25** is not magnetized and the pressure of the fuel prevailing in flow passages **23**, **33** and **36** is equal to the pressure (5 atm) of the fuel prevailing in a low-pressure chamber **18**, the interval L_5 between the upper end of the magnetic core **25*a*** of the electromagnet **25** and the lower surface of an armature **26** attached to the upper end of a needle valve **47** is 0.3 mm and the interval L_6 between the extremity of the projection **75** of the cap **47** and a stopper rod **29** is 0.2 mm. In the sixth embodiment, the preload on a compression coil spring **28** is 5 kg and that on a compression coil spring **30** is 11 kg.

When the coil **25*b*** of the electromagnet **25** is energized, the armature **26** is attracted toward the electromagnet **25** to disconnect flow passages **33** and **36** from each other by bringing a sealing face **41** formed on the lower end of the needle valve **47** into close contact with a seat surface **40**. In this state, the interval L_5 is 0.1 mm.

When the coil **25b** of the electromagnet **25** is de-energized, the needle valve **27** is raised by the resilience of the compression coil spring **28** to connect the flow passages **33** and **36** and, consequently, the high-pressure fuel flows into a spring chamber **32**. The high-pressure fuel raises the needle valve **27** further against the resilience of the compression coil spring **30** after the needle valve **27** has come into contact with the stopper rod **29** until the stopper rod **29** is stopped by the projection **75** of the cap **47**.

The solenoid valve in the sixth embodiment is advantageous over the solenoid valve in the first embodiment in the following respect.

In the first embodiment, the stopper rod **29** separates from the needle valve **27** by inertia and moves further upward, as viewed in FIG. 2 after the needle valve **27** has been stopped by the boss **48** formed on the inner surface of the upper wall of the upper housing **38**, and then the stopper rod **29** is moved downward by the resilience of the compression coil spring **30** and pushes the needle valve **27** downward. Consequently, if the pressure of the fuel in the spring chamber **32** is not sufficiently high, there is the possibility that the lift of the needle valve **27** decreases for a moment. Meanwhile, in the sixth embodiment, the stopper rod **29** is stopped by the projection **75** of the cap **47** when the needle valve **27** is raised at the maximum lift and hence the stopper **29** is unable to separate from the needle valve **27**. Thus, the needle valve **27** can be secured at the maximum lift.

The solenoid valve of the present invention is not limited in its practical application to use in combination with the face cam type fuel injection pump; the solenoid valve of the present invention is applicable also to use in combination with inner cam type fuel injection pumps, line fuel injection pumps and devices other than fuel injection pumps.

Although the invention has been described in its preferred form with a certain degree of particularity, obviously many changes and variations are possible therein. It is therefore to be understood that the present invention may be practiced otherwise than as specifically described herein without departing from the scope and spirit thereof.

We claim:

1. A solenoid valve for a fuel injection pump comprising:

a valve body defining a bore therein and defining a first passage connected to a high-pressure side of the fuel injection pump and a second passage connected to a low-pressure side of the fuel injection pump, said valve body having a valve seat disposed coaxially with said bore between said first and second passages;

a cylindrical valve element disposed movably within said bore between a closed position wherein said valve element abuts said valve seat, disconnecting said first passage from said second passage, and an open position wherein said valve element is displaced from said valve seat, connecting said first passage to said second passage, said cylindrical valve element having a substantially uniform cylindrical surface extending substantially parallel to an opening direction thereby substantially eliminating a surface upon which a pressure can act to bias said valve element in the opening direction when said valve element is in the closed position;

first biasing means for biasing said cylindrical valve element towards the open position;

an armature disposed on said valve element, said armature being contained in a space communicating with the low-pressure side; and

an electromagnet having a coil spaced axially from said armature, said electromagnet urging said armature towards the closed position when said coil is energized.

2. A solenoid valve according to claim **1** further comprising second biasing means for positioning said armature within a predetermined range against a biasing force of said first biasing means when said coil is de-energized.

3. A solenoid valve according to claim **2**, further comprising a stopper member disposed between said second biasing means and said valve element, said stopper member cooperating with said second biasing means to position said armature in said predetermined range when said second biasing means acts against said first biasing means when said coil is de-energized.

4. A solenoid valve according to claim **2**, further comprising a stopper rod disposed between said second biasing means and said cylindrical valve element, said stopper rod being biased by said second biasing means so as to contact said cylindrical valve element and to remain in contact with said cylindrical valve element when said cylindrical valve element is biased in said opening direction, said stopper rod cooperating with said second biasing means to position said armature in said predetermined range when said second biasing means displaces said stopper rod to a maximum extent.

5. A solenoid valve according to claim **1**, wherein said first passage is connectable to a high-pressure side and wherein said second passage is connectable to a low-pressure side such that a high-pressure fluid can flow from said high-pressure side to said low-pressure side when said valve element is in the open position, and wherein said first biasing means includes said high-pressure fluid acting upon said cylindrical valve element when said cylindrical valve element is displaced from said valve seat.

6. A solenoid valve for a fuel injection pump comprising:

a valve body defining a bore therein and defining a first passage connected to a high-pressure side of the fuel injection pump and a second passage connected to a low-pressure side of the fuel injection pump, said valve body having a valve seat disposed coaxially with said bore between said first and second passages;

a cylindrical valve element disposed movably within said bore between a closed position wherein said valve element abuts said valve seat disconnecting said first passage from said second passage and an open position wherein said valve element is displaced from said valve seat connecting said first passage to said second passage, said cylindrical valve element having a substantially uniform cylindrical surface extending substantially parallel to an opening direction thereby substantially eliminating a surface upon which a pressure can act to bias said valve element in the opening direction when said valve element is in the closed position,

said valve element contacting said valve seat in the closed position along a contacting interface of said valve seat such that a diameter of said contacting interface is not substantially smaller than a diameter of said cylindrical valve element thereby substantially eliminating a surface upon which a pressure can act to bias said cylindrical valve element in an opening direction when said cylindrical valve element is in the closed position;

first biasing means for biasing said cylindrical valve element towards the open position;

an armature disposed on said valve element; and

an electromagnet having a coil spaced axially from said armature, said electromagnet urging said armature towards the closed position when said coil is energized.

7. A solenoid valve according to claim **6** further comprising second biasing means for positioning said armature within a predetermined range against a biasing force of said first biasing means when said coil is de-energized.

8. A solenoid valve according to claim **6**, wherein said cylindrical valve element has a valve sealing face having a substantially conical shape and wherein said valve seat also has a substantially conical shape, an apex angle of said conical shape of said valve seat being smaller than an apex angle of said conical shape of said valve sealing face.

9. A solenoid valve according to claim **7**, further comprising a stopper member disposed between said second biasing means and said valve element, said stopper member cooperating with said second biasing means to position said armature in said predetermined range when said second biasing means acts against said first biasing means when said coil is de-energized.

10. A solenoid valve according to claim **7**, further comprising a stopper rod disposed between said second biasing means and said cylindrical valve element, said stopper rod being biased by said second biasing means so as to contact said cylindrical valve element and to remain in contact with said cylindrical valve element when said cylindrical valve element is biased in said opening direction, said stopper rod cooperating with said second biasing means to position said armature in said predetermined range when said second biasing means displaces said stopper rod to a maximum extent.

11. A solenoid valve according to claim **6**, wherein said first passage is connectable to a high-pressure side and wherein said second passage is connectable to a low-pressure side such that a high-pressure fluid can flow from said high-pressure side to said low-pressure side when said valve element is in the open position, and wherein said first biasing means includes said high-pressure fluid acting upon said cylindrical valve element when said cylindrical valve element is displaced from said valve seat.

12. A solenoid valve for a fuel injection pump comprising:

a cylindrical housing having an open end and a substantially closed end, said substantially closed end defining a hole therethrough;

a valve body disposed within said cylindrical housing and coaxially with said hole, said valve body defining a bore therein and defining a first passage connected to a high-pressure side of the fuel injection pump and a second passage connected to a low-pressure side of the fuel injection pump, said valve body having a valve seat disposed coaxially with said bore between said first and second passage, said valve seat has a substantially conical shape;

an electromagnet having a coil wound around said valve body for generating electromotive forces;

a cylindrical valve element having a substantially conically shaped valve sealing face disposed movably within said bore between a closed position wherein said valve element abuts said valve seat disconnecting said first passage from said second passage and an open position wherein said valve element is displaced from said valve seat connecting said first passage to said second passage;

an apex angle of said conical shape of said valve seat being smaller than an apex angle of said conical shape of said valve sealing face thereby substantially eliminating a surface upon which a pressure can act to bias said valve element in an opening direction when said valve element is closed;

an armature disposed in said cylindrical valve element; and

a stopper rod slidably mounted in and projectable through said hole to abut said valve element and position said armature in a predetermined position when said electromagnet is de-energized.

13. A solenoid valve according to claim **12** further comprising biasing means for biasing said cylindrical valve element in said opening direction.

14. A solenoid valve according to claim **12**, further comprising means for controlling movement of said stopper rod in said opening direction.

15. A solenoid valve according to claim **12**, further comprising biasing means for biasing said cylindrical valve element towards said closed position.

* * * * *